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Forest Service

Soil Resource Report

For the Fourmile Project

Eagle River-Florence RD

Chequamegon-Nicolet National Forest

Prepared By:
Mark Farina, Forest Soil Scientist

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EXECUTIVE SUMMARY

In this report I looked at how the proposed Fourmile Project would affect long-term soil productivity. I determined that activities associated with timber harvest, mechanical site preparation, prescribed fire and road construction in this proposal would result in measurable soil disturbance, but total detrimental soil disturbance would be well under acceptable thresholds. I identified the soil type(s) for each proposed treatment area and assigned a rating of potential risk using criteria-based interpretations derived from standard soil rating criteria. I measured the effect to soil by estimating the percentage of a treatment area that would be traveled by heavy equipment and the potential for that affected area to be compacted, rutted, displaced, or eroded. I also estimated the potential effects from nutrient loss after tree bole removal, and prescribed fire. My estimates include consideration of soil resource protection measures that are known to control the extent and duration of disturbance. I compared the estimated percentage of detrimental disturbance per treatment area, to the measurement standards and threshold values dictated by the Eastern Region of the Forest Service to determine when soil disturbance effects are unacceptable (limits of change for soil properties are exceeded and result in major changes to soil quality and productivity). I considered previous impacts of management on these same areas to determine cumulative effects.

I found the soil resource on more than 99 percent of the project areas is currently in good condition and soil properties are well within their natural range of variability. Soils on project sites pose a low risk potential for detrimental disturbance from the conventional ground-based logging, mechanical site preparation, prescribed fire and road construction activities proposed. The project would adhere to Forest Plan standards and guidelines and resource protection measures for specific soil types, eliminating or minimizing potential adverse soil resource impacts. At most, an additional 1 to 2 percent of the soil resource in the harvest treatment areas would sustain long-term detrimental impacts from proposed activities. About 97 percent of the treatment areas would remain in a non-detrimentally disturbed condition, which meets National and Regional soil quality standards. Based on my findings of minimal direct and indirect effects from soil compaction, rutting, erosion, displacement, or nutrient loss, I conclude that the action alternative would not impair the long-term productivity of the treatment areas proposed or any adjacent areas.

INTRODUCTION

Issue

Soil disturbance caused by heavy equipment used for harvesting or site preparation activities, and prescribed fire may have negative effects on soil physical, chemical and biological properties and could reduce long-term forest site productivity. Use of heavy rubber-tired or tracked equipment creates risk of soil compaction, rutting, displacement, or erosion. Removal of merchantable tree boles, and prescribed fire could affect total site nutrients. If the severity, areal extent, and duration of soil disturbance are great enough to negatively influence the availability of water, nutrients, and/or oxygen to tree roots, then the ability of a site to sustain productive forest growth could be reduced. The Fourmile Project proposes activities that would require heavy equipment to harvest and remove merchantable tree boles, construct and decommission roads, prepare sites for natural regeneration or planting, and the use of prescribed fire.

Background

The Fourmile Project action alternative proposes about 11,803 acres of treatment area, 1.2 miles of new permanent road construction, 46.4 miles of existing road reconstruction, 147.2 miles of road decommissioning, 48.9 miles of road conversion to trails, 0.2 miles of new temporary road construction, 354 acres of proposed and optional mechanical site preparation treatments for natural regeneration or planting of trees, 5.3 miles of fire control line, and 334 acres of prescribed fire. There would be about 229 acres of ladder fuels treatments and slash disposal in the action alternative.

The soil resources of the CNNF are mapped and characterized within a multi-scale, hierarchical, ecological classification framework as described by Cleland et al (1997, 20p). Land type phases (LTP) provide the most site-specific scale of soil information by defining similar ecological conditions relating to soil texture, moisture, nutrients, drainage class, slope and other physical, chemical and biological characteristics. LTP maps have been intersected with proposed treatment areas to identify the specific soil type(s) for each area (Fourmile Soil Resource Report Appendix A). LTP/soil maps and descriptions are available at the CNNF Rhinelander office.

The “affected area” for analysis of direct and indirect effects of the proposed activities to the soil resource is that portion of a treatment area where activities would take place. As quantified in the following Measures section, equipment would travel about 13 percent of the acres harvested, about 3.0 percent of the acres mechanically treated for planting or natural regeneration, and up to 2.8 percent of treatment acres could be treated with prescribed burning. Potential effects to the soil resource are reasonably confined to the soil directly beneath where the activity would take place, such as the operation of machinery to cut and remove trees. For example, heavy equipment causing soil compaction that reduces pore space for air, roots and water within a portion of one treatment area does not affect pore space on adjacent areas. The analysis boundary for cumulative effects will be the Land Type Phases (LTP) within treatment areas for the Fourmile Project. The land dedicated to the existing road and trail systems within the project area is considered part of the infrastructure required to access and manage the CNNF and is excluded from the affected area when analyzing potential soil disturbance for this project.

The proposed treatment areas occur within 33 different LTP map units that are occur in the Argonne Outwash Plains (41%), Nicolet Hills (29%), Vilas-Oneida Outwash Plains (25%), and the Iron River/Argonne Drumlins (5%) Land Type Associations, LTA. The primary glacial landforms are comprised of pitted and unpitted outwash plains, as well collapsed hummocky outwash topography. Topography is nearly level to steep, with about 89 percent of the treatment areas having <15 percent slopes, and 11 percent of the areas with slopes ranging from 15-45 percent. Soil surface texture is loamy material (sandy loam to loam) for 74 percent, sandy material for about 24 percent, silty material (silt loam) for 1 percent, and mucky for about 1 percent of the treatment areas. Soil internal drainage class is moderately-well (10%), well (51%), somewhat excessive to excessive (34%), and somewhat poorly to poorly drained (5%) for the treatment areas. Table 1 displays the names of soil types that overlap with treatment areas proposed in the Fourmile Project, along with associated percent of total acres for each action alternative. Soil types associated with each treatment area are listed in Appendix A, with more detailed ratings for potential effects from proposed activities.

Table 1. Soil Type and Acres (%) for the Proposed Action

Soil Type	Action Alternative Acres (%)
Padus-Pence	29
Padus	20
Vilas	13
Pence-Vilas	9
Argonne-Sarwet	4
Pence	4
Karlin	3
Sayner	3
Tipler	3
Au Gres	2
Laona-Sarona	2
Worcester	2
Croswell	1
Cublake	1
Kinross	1
Rubicon	1
Capitola	<1
Fence	<1
Fordum	<1
Gastrow	<1
Keweenaw	<1
Manitowish	<1
Minocqua	<1
Mudlake	<1
Padus-Soperton	<1
Padus-Wabeno	<1
Padwood	<1
Pelissier	<1
Pits, Gravel	<1
Sayner-Rubicon	<1
Stambaugh	<1
Wabeno-Goodman	<1
Wabeno-Goodwit	<1
Wormet	<1
Total	100

There are no known areas within the Fourmile Project boundary where productivity of the land has been permanently impaired due to past vegetation management activities (USDA Forest Service, 2004c p3-39). On-site monitoring of soil resource impacts within the Eagle River-Florence Ranger District has shown no long-term impairment of the land from similar project activities on similar soil types as listed in Table 1 (USDA Forest Service, 2000a, 2002a, 2004b, 2006c, 2007c, 2015b). All proposed treatment areas have been field investigated by resource specialists collecting site specific data for this project. About 6,439 acres (54%) of the stands proposed for treatment have had no previous harvest, about 5,521 acres (46%) have had one or more previous harvests in the past 30 years; as documented in the CNNF timber stand history files. All treatment areas would have had harvests dating beyond the 30 year records. Currently, more than 99 percent of all acres proposed for treatment within the project area boundary are maintained in a non-detrimentally disturbed condition, with less than 0.5 percent (60 acres) estimated to be detrimentally disturbed as a log landing, main skid trail, or temporary road from previous management activities.

Measures, Indicators, and Thresholds

Risk of soil disturbance exists whenever ground-based equipment is used in forest operations. The areal extent of potential disturbance for each treatment unit is equal to the amount of ground traveled by the equipment needed to accomplish the activity. A 2002 study on the adjacent Ottawa NF found skid trails comprise 16 percent and haul roads one percent of total managed stand area, on average (Buckley et al. 2002, p36). Sale administrators on the CNNF calculate skid trails comprise about 11 percent or less of a managed stand with the equipment used in 90 percent of the harvest operations (Schumacher, 2002). Harvesters have a 24 to 32 foot reach and average 45 to 50 feet between trails. Annual timber sale monitoring since 1998 continues to indicate landings and temporary haul roads occupy less than 1 percent of total managed stand area, on average, across the CNNF (USDA Forest Service, 2008a, 2008b, 2008c, 2009a, 2009b). Harvest layout, type of equipment, operator knowledge, and careful sale administration also influence the areal extent of potential disturbance. For this report a conservative estimate of 13 percent is used as the measure of ground traveled within a managed stand for all harvest activities. Equipment used to mechanically treat vegetation and/or scarify soil to prepare sites for planting or natural regeneration may travel from 50-75 percent of a treatment area (USDA NRCS, 1998, p537-9).

Soils vary in resiliency to heavy equipment impacts based on specific physical properties such as surface texture, wetness, and soil strength at the time of operation. To measure the potential risk of operating heavy equipment on the proposed treatment areas, criteria-based interpretations derived from standard soil rating criteria are used to assess each site-specific soil type (USDA NRCS, 1998, p537-6). Interpretive ratings have been generated for each soil type on the CNNF from the National Soil Information System (NASIS) database, where the soil properties of each LTP on the Forest are stored. A rating ranging from slight to very severe is generated for each potential hazard or activity such as potential for erosion, potential for rutting, or harvest equipment operability. Ratings are given for the most limiting soil and season and describe the degree to which the hazard is likely. Ratings also identify the limiting factor and suggest precautions needed to minimize potential soil disturbance from the activity. In addition, the risk of soil disturbance is further evaluated based on best available and applicable research, site specific field observations, monitoring of similar activities on many treatment areas with the same soil type, and the professional judgment of an experienced soil scientist.

The interpretive ratings that measure the potential for soil disturbance are then used to develop design measures that reduce or eliminate the risk to degrade the soil resource. For example, a treatment area rated severe for potential soil rutting due to wetness and low strength, would be assigned a frozen ground only operating requirement, thereby reducing the risk for soil rutting to slight, with no detrimental effects to the soil resource expected.

Measurement techniques defined by Region 9 (USDA Forest Service, 2012a) are used to measure existing soil disturbance from previous activities. These methods are primarily ocular qualitative assessments that are followed up by quantitative monitoring where management practices appear to have produced unacceptable results. Quantitative monitoring is done in accordance with the Region 9 soil quality standards and guidelines using the Forest Soil Disturbance Monitoring Protocol (FSDMP). (Page-Dumroese, 2009) The FSDMP defines soil indicators into classes that can be measured consistently, efficiently and economically. It provides estimates of total areal site soil disturbance and applies confidence intervals around the monitoring results.

The estimates are based on sample size determined by variability within a predetermined confidence level. (Page-Dumroese, 2009, p. 2)

Field monitoring of soil resource impacts for LTPs across the CNNF has consistently shown that initial harvest entries leave on average between 1 to 3 percent of a treatment area in a detrimentally disturbed condition from compaction of major skid trails, temporary haul roads and log landings (USDA Forest Service, 2001c, 2003a, 2004a, p4). Second harvest entries utilize existing trails, roads and landings and may detrimentally disturb about 1 to 2 percent of additional land area (USDA Forest Service, 2000a, p3). Subsequent harvest entries utilize the existing trails, roads and landings with little additional detrimental soil disturbance expected. Mechanical site preparation equipment delivers fewer pounds per square inch to the ground than loaded harvest equipment and generally does not cause detrimental soil disturbance.

The CNNF goal for soils, as described in the Chequamegon-Nicolet National Forests Land and Resource Management Plan, is to provide desired physical, chemical and biological soil processes and functions on the Forests to maintain or improve soil productivity (USDA Forest Service, 2004d, p1-4). The Forest Service Manual for Soil Management in Region 9 sets soil quality standards (USDA Forest Service, 2012a) and measurement techniques to help determine detrimental soil conditions.

Forest-wide standards and guidelines for soils (USDA Forest Service, 2004d, p. 2-3) states the CNNF will use the R9 manual guidelines for measuring detrimental disturbance threshold values for soil displacement, erosion, rutting, nutrient loss, compaction, burning, and maintaining ground cover. Region 9 minimum measurement standards include:

- Detrimental erosion – presence of rills, gullies, pedestals and soil deposition.
- Detrimental displacement – removal of the forest floor and surface mineral soil removal, gouging or piling. Surface soil mixed with subsoil or subsoil partially or totally exposed.
- Detrimental compaction – Increased compaction and soil structure change from granular to massive or platy, at a depth greater than 30 centimeters.
- Detrimental rutting – wheel tracks and depressions highly evident with depth greater than 10 centimeters.
- Detrimentally Burned – Depth of char is greater than 5 centimeters. Duff and litter layer completely consumed. Surface soil is water repellent. Surface is reddish or orange in color.

In addition to the Region 9 standards above, the CNNF also implements the following measurement standards:

- Detrimental loss of productivity – a 15% (by area) reduction in long-term soil productivity based on any combination of the above thresholds, organic matter loss and/or impaired nutrient cycling.
- Detrimental soil disturbance threshold (performance based) - 8% maximum (by area) based on properly executed management plans and sale administration.

The indicator of the effects of soil disturbance is the intensity, areal extent and duration of the impacts for each treatment area. Detrimental disturbance exists when the severity of soil impacts exceeds the R9 measurement standards over a large enough area for a long enough time, to cause an unfavorable ecosystem response. The results of this report take into careful consideration on how the proposed treatment areas and ecosystem will respond to each particular soil property disturbance. The ways in which different ecosystems respond to soil property change are dependent on multiple variables such as geography, parent material, climate, and treatment type. For this analysis, I analyzed soil resource reports and post-harvest monitoring results from near-by areas, on similar soil and treatment types to determine what the acceptable upper limit of detrimental disturbance is. (USDA Forest Service, 2000a, 2002a, 2004b, 2006c, 2007c, 2015a, 2015b, 2015c, 2017a, 2017b) My analysis concluded that it would take greater than a 15 percent total average, of detrimental soil disturbance, as defined above, across all treatment areas, before there would be any measureable, negative and long term sustained ecosystem response on this particular project area.

Using Region 9 soil quality standard measurements, at least 85 percent of a treatment area must be maintained in a non-detrimentally disturbed condition. If 15 percent or more of a treatment area is in a detrimentally disturbed condition, then the area is considered impaired, unless restoration is successfully

implemented. For this report, duration for short-term effects to soil is considered to be less than 10 years or the shortest amount of time between treatment entries. Duration for long-term effects is considered to be greater than 20 years. A 20 year time period is also compatible to the CNNF LRMP planning period and the average time between timber harvest thinning, selection, and shelter-wood activity. Clear cut rotations are typically 40 to 50 plus years.

Performance-based detrimental soil disturbance thresholds are designed to measure how effective we are implementing soil resource protection measures under current management and policy. This threshold doesn't represent a tipping-point for adverse ecological change, but rather represents a tipping-point at which soil protection measures are not being properly implemented on the ground. Measurements above this threshold indicate that soil protection measures are failing either through improper project design or improper sale administration. Post-harvest disturbance monitoring (<1 year) indicates that 8% detrimental disturbance (by area) is a reasonable upper-limit that we can expect to see across all soil types under current soil guidelines and current logging technology. (USDA Forest Service, 2015a p4) On average, we typically see measures between 0 and 3 percent on the more coarse textured soils such as those in this project area.

FINDINGS

The effects of the proposed actions were assessed on a site-specific basis to determine if the intensity, extent and duration of potential soil disturbance would cause appreciable change in soil properties to be considered detrimental to the long-term productivity of the land. The action alternative proposes actions that have the potential to change soil properties through erosion, displacement, compaction, rutting, or nutrient removal.

The magnitude of potential direct, indirect and cumulative effects on the soil resources is estimated from standard soil ratings and criteria-based interpretations, and includes consideration of assigned resource protection measures. These measures are listed in Appendix A and discussed in the effects analysis below. Protective measures include site-specific design features, Forest Plan standards and guidelines, and forestry best management practices that are assigned where appropriate to avoid or minimize potential negative effects to the soil resource. Tables in the final Fourmile Project EA will provide a complete list of design features and/or mitigation measures for each treatment area.

Implementation and effectiveness monitoring of similar project actions across the CNNF has indicated site-specific design measures and best management practices to be highly effective in minimizing potential adverse effects to soil and water quality (USDA Forest Service, 2001b, 2002a, 2003b, 2004a, 2005a, Shy and Wagner, 2007, p33). Proposed treatment areas (harvest, mechanical site preparation, and roads) would be monitored during project implementation by Forest Service personnel to ensure contract specifications and design features are followed. Randomly selected treatment areas would be monitored post harvest by the forest soil scientist as part of a forest-wide soil monitoring program, to evaluate whether ground conditions meet acceptable limits of change for measurable and observable soil properties.

No Action Alternative

Direct and Indirect effects (site-specific):

Soil Compaction and Rutting

The potential for soil compaction and rutting is very low since no new activities involving operation of heavy equipment in the project area are proposed. Existing compaction from previous harvest entries would gradually be mitigated through natural soil forming processes, plant root development, and freeze-thaw cycles (NCASI, 2004, p38). The no action alternative would have indirect effects on soil resources from soil compaction or rutting. Under this alternative, approximately 147.2 miles, or 214 acres (assuming 12' road width) of existing roads would not be decommissioned, and approximately 48.9 miles or 35.6 acres (assuming 6' walking base) of roads converted to trails would not occur and therefore these lands would not be converted back to productive land base. Existing roads are not considered part of the productive land base,

so converting these areas back to productive land base would, over time; result in a net increase of approximately 249.6 acres of productive soil resources.

Soil Erosion and Displacement

The potential for soil erosion and displacement is very low since no new ground disturbing activities are proposed in this alternative. Geologic erosion would continue at a minimal rate of less than 0.18 tons/acre/year (Patric, 1976, p572). The no-action alternative would have no new direct or indirect effects on soil resources from erosion or displacement.

Soil Productivity

The potential for impacts to inherent soil productivity are very low since there would be no new ground or vegetation disturbing activities. Natural soil formation processes would continue, biomass would accumulate, organic matter would accumulate and be incorporated into the soil surface, and the biological and geo-chemical cycles would continue. Inputs to the system include atmospheric deposition and weathering of parent materials. Annual nutrient balances based on estimated inputs and outputs would tend to increase as succession progresses (Pritchett, 1987, p190). There would be no adverse nutrient loss with the no-action alternative, therefore no appreciable effects to the soil resource or long-term productivity of the land. The decommissioning of 147.2 miles of existing road and the conversion of roads to trails would not be completed as proposed in the action alternative, therefore returning this land (249.6 acres, assuming a 12' road width and 6' trail width) to productive soil resource over time would not officially begin by implementing the no-action alternative, although any unused portions of these roads may already be covered with woody vegetation. About 229 acres of Wildland Urban Interface (WUI) hazardous ladder fuel reduction and slash disposal may be required through balsam bough cutting permits, or by manual hand removal. There is no expected risk to the long-term productivity of the land from this activity.

Cumulative effects:

There are no new direct, indirect, or cumulative detrimental effects to the soil resource as a result of the no-action alternative. The cumulative detrimental effects would remain equal to the past detrimental effects which are conservatively estimated to be 0.5 percent (60 acres) of the Fourmile Project.

Action Alternative

Direct and Indirect effects (site-specific):

These alternatives have potential to affect soil resources through timber harvest operations, road construction, road decommissioning and mechanical site preparation and prescribed burning. Appendix A lists treatment area specific information including soil type, rating hazard, soil limiting factor, and design measures. The following tables summarize the site-specific ratings by type of activity or potential soil disturbance. All ratings given are before soil resource protection measures have been assigned.

A rating of slight indicates little or no restrictions are necessary for equipment use, or no rutting or erosion is likely. A moderate rating indicates one or more limitations reduce site suitability for equipment use, or ruts are likely without some seasonal restrictions, or erosion control measures may be needed. A severe rating indicates limitations that make equipment use difficult without major seasonal restrictions or special equipment, or the soil would rut readily without operating restrictions, or significant erosion would be expected without costly control measures. Based on post-harvest soil monitoring results, implementing the identified site-specific design measures will reduce the potential risk of soil impacts by a minimum of one rating level. Thus, a rating of moderate for erosion would be reduced to slight, and so on.

The following tables summarize the potential for soil impacts from project actions. Table 2 displays equipment use ratings for acres of proposed treatment. These ratings include equipment use for harvesting, road construction, mechanical site preparation, and prescribed burning.

Table 2. Woodland Equipment Use Rating.

Soil Disturbance Risk	Action Alternative Acres (%)
Slight	9708 (83)
Moderate	1,101 (9)
Severe	863 (8)

Table 3 displays treatment acres rated for potential soil compaction and rutting from all proposed activities.

Table 3. Potential for Soil Compaction and Rutting.

Soil Disturbance Risk	Action Alternative Acres (%)
Slight	10,978 (94)
Moderate	138 (1)
Severe	556 (5)

Table 4 displays treatment acres rated for potential soil erosion and displacement from all proposed activities.

Table 4. Potential for Soil Erosion and Displacement.

Soil Disturbance Risk	No Action Acres (%)
Slight	10,364 (88)
Moderate	1,001 (9)
Severe	307 (3)

Soil Compaction and Rutting

As shown in Table 3 above, potential for soil compaction and rutting from operation of heavy equipment is slight for 94 percent of the treatment areas in the action alternative that have sandy textured, moderately-well to excessively drained soils. The operating season would be year round, except for periods of excessively wet conditions, such as annual spring thaw or major rainfall events.

Potential for compaction and rutting is moderate for about 1 percent of the treatment areas in the action alternative that are on a finer textured, moderately-well to well-drained soils. These fine sandy loam and silt loam soils hold moisture in surface horizons longer and lose strength when near saturation. These soils hold up well to equipment use when dry because as soil moisture content decreases, soil strength increases and compaction potential decreases (NCASI 2004, p2). Therefore, a protective measure restricts the operating season to winter (frozen ground) or dry summer/fall for each treatment area with a moderate rating, to

minimize the potential for detrimental soil disturbance. All sites meeting these criteria are identified by “winter or dry summer/fall” in the “Recommended Operating Season” column of Appendix A.

Potential for compaction and rutting is severe for about 5 percent of the proposed treatment areas in the action alternative due to poor internal drainage on all or a portion of the treatment areas. These soils are wet near the surface year round and a design measure restricts equipment operation to frozen ground only (Appendix A shows specific treatment areas, type of treatment and associated design measures). Five year results of a long-term site productivity study concluded that harvesting aspen when soils were frozen had little effect on physical soil properties and produced a fully stocked stand of aspen suckers (Stone and Elioff, 1998, p56-57). Effects to the physical properties of all soils with poor internal drainage are minimized through frozen ground operation of heavy equipment, regardless of forest type. By restricting the harvest operations to frozen ground, the potential risk for compaction and rutting is reduced to slight for these treatment areas.

Potential for compaction and rutting is also reduced by operating low ground pressure equipment over snow, forest floor, logging slash, and surface rock. Harvesters with 24 inch wide tracks, and 24 inch wide, 4 to 8 wheeled rubber-tired forwarders is the type of equipment commonly used on the CNNF. A Michigan study intentionally tested the latest harvesting equipment on wet, fine sandy loam soil and found no compaction or rutting that exceeded acceptable limits (Miller et al, 2001, p3). About 94 percent of the soils in the proposed treatments areas, in the action alternative, are moderately-well to excessively drained, with coarse textures that provide good support for heavy equipment when the surface is dry, with minimal rutting and compaction risk.

During project implementation, on-site inspections are performed by sale administrators to ensure contract provisions to protect soil resources are enforced. Main trails near log landings have repeated use by harvesting equipment and therefore, have a higher potential for compaction, depending on moisture conditions if the ground is not frozen. There would be an increase in soil surface strength and density (bulk density) on the main skid trails from multiple passes of equipment, with detrimental compaction (increased compaction and soil structure change from granular to massive or platy, at a depth greater than 30 centimeters) expected on about 1 to 2 percent of the treatment areas. Potential for long-term detrimental compaction or rutting is minimized by limiting the operating conditions to dry or frozen ground. Soil scientists and resource specialists have monitored similar sites harvested on these and similar LTPs/soils. Findings to date indicate no evidence of reduced productivity due to compaction and rutting. (USDA Forest Service, 2000a, 2002a, 2004b, 2006c, 2007c, 2015a, 2015b)

Log landings where wood is temporarily stored until it can be trucked away are primarily located adjacent to haul roads in the road right of way and would be detrimentally compacted during harvest operations. The decking and removal of wood products would occupy about ¼ to ½ acre for each 60 to 80 acres of harvest in most cases, or about 0.4 to 0.6 percent of a harvest unit, and would not add appreciably to the total areal extent of detrimentally disturbed soil. Some landings would be scarified and re-vegetated, and some would be left to recover naturally. The period of time for natural recovery varies by soil characteristics and severity of compaction and while freeze-thaw cycles may hasten recovery, the effects may be assumed to persist for several decades (NCASI, 2004 p62).

The proposed action alternative includes about 1.2 miles of new road construction (20’ maximum clearing width assumed), which would compact new soil areas and change the land use for about 2.9 acres of land from productive forest to part of the permanent transportation system used to manage the CNNF. Permanent roads are not part of the productive land base and are not considered in assessing detrimental compaction and rutting.

The proposed action alternative includes about 46.4 miles of existing road reconstruction to improve road surface conditions for the intended level of use (see Appendix B for road identification, lengths and soil types). Permanent roads and trails are not part of the productive land base and are not considered in assessing detrimental compaction and rutting.

The proposed action alternative includes decommissioning 147.2 miles of existing roads; returning those areas back to productive land base. Decommissioning of these existing roads may involve discing to loosen compaction and/or natural processes would be allowed to eliminate existing compaction over time, returning this land to productive forest.

The action alternative proposes constructing one 0.2 mile (0.7 acres, assuming a 28' maximum clearing width) temporary road (see Appendices B for road identification, lengths and soil type). Temporary roads are not part of the permanent transportation system and are subject to soil quality standards. The soil within about a 28 foot wide clearing limit could be detrimentally compacted during construction and the 14 foot road surface would be compacted from repeated hauling of wood products. This would be a short term effect, as this temporary road would be decommissioned upon completion of the proposed projects (USDA Forest Service, 2004d p2-36). Decommissioning the new temporary road and the 147.2 miles of existing roads as proposed in the action alternative involve discing to loosen compaction and/or allow natural processes to eliminate existing compaction over time, returning this land to productive forest.

The action alternative proposes to use tractor or skidder attached equipment to roller chop, disc trench or salmon blade scarify a maximum or 354 acres of the treatment areas for planting or natural regeneration. All areas proposed for mechanical site-prep are also proposed for a harvest treatment. Soil compaction and rutting risk is slight (99%) for the action alternative mechanical site-prep treatment areas. Areas proposed for site-prep are rated slight for rutting and compaction risk due to surface texture (sandy loam and coarser), and drainage (well to somewhat excessively). Site preparation equipment delivers fewer pounds per square inch to the ground surface than loaded harvest equipment, but does travel about 50-75 percent of a treatment area and has potential for compaction and rutting. The same seasonal restrictions assigned for harvesting would limit equipment use to dry or frozen ground conditions when soil strength is high, minimizing risk for soil compaction or rutting from the lighter mechanical site preparation equipment. The salmon blade equipment would actually reduce surface compaction on main skid trails that are crossed. There would be no short or long-term detrimental compaction or rutting expected from site preparation activities proposed in the action alternatives.

About 5.3 miles of dozer blade or fire plow constructed mineral soil line are proposed in the action alternative to contain fire in prescribe burn areas. Soil compaction and rutting risk is slight (100%) for the action alternative treatment areas. Areas proposed for site-prep are rated slight for rutting and compaction risk due to surface textures (loamy sand), and drainage (excessive). There would be no detrimental compaction or rutting from one or two passes with a tracked dozer during fire line construction on these soils.

About 229 acres of Wildland Urban Interface (WUI) hazardous ladder fuel reduction and slash disposal in the action alternative will be accomplished through the timber sale activities described, through balsam bough cutting permits, or by hand removal. There is no additional risk of soil compaction or rutting from this activity.

In summary, harvest activities would be designed to utilize existing roads, main skid trails, landings and back in spurs to the extent possible to avoid or minimize soil compaction and rutting across treatment areas. Operating seasons based on soil type would be stipulated in the timber sale contracts and soil moisture conditions and harvest equipment impacts would be monitored by Forest Service timber sale administrators. Harvesting operations would be stopped when soils become saturated to the extent that detrimental compaction and rutting is likely or begins to occur. The following Forest Plan guidelines would apply to all treatment areas (see Appendix A).

- Operate heavy equipment only when soils are not saturated or the ground is frozen (USDA Forest Service, 2004d p. 2-3). Follow the "Recommended Operating Season" column in Appendix A to apply this Forest Plan guideline by stand and soil type.
- Designate the location of roads, trails, landings, main skid trails, and similar soil disturbing activities. Stabilize disturbed sites during use and re-vegetate after use to control erosion (USDA Forest Service, 2004d, p. 2-3).
- Decommission all temporary roads upon completion of use. (USDA Forest Service, 2004d, p2-36).

There would be long-term detrimental soil compaction on main skid trails and landings from operation of heavy equipment on about 1 to 2 percent of each treatment area for the action alternative. Post-harvest monitoring reports referenced throughout this report consistently show that initial harvest result in 0 to 3 percent detrimental soil disturbance, on average, and winter operations result in 0 to 2 percent detrimental soil disturbance. In 2017, 115 post-harvest CNNF soil monitoring reports, spanning 2006 to 2015, were compiled and analyzed. These reports included all 5 Districts and all soil textures, drainage classes and harvest types. The compiled results showed on average and soon after harvest (typically <1 year),

detrimental soil disturbance occurred on 1.1 percent of frozen ground harvests and 1.8 percent of non-frozen ground harvests. (USDA Forest Service, 2017a)

The extent, intensity and duration of compaction would be minimized for about 98 percent of all treatment areas proposed through operating requirements and soil protection guidelines. This is a conservative estimate, yet well within Region 9 soil quality standards explained on page 3 and 4 of this report. Long-term productivity of the land would not be impaired by soil compaction or rutting from the proposed activities.

Soil Erosion and Displacement

As shown in Table 4 above, the potential for erosion and displacement is slight for 88 percent of the treatment areas proposed for the action alternative, indicating little or no erosion or displacement is likely. These areas have slopes that range up to 15 percent, but commonly have 4 to 10 percent gradients.

The potential for erosion and displacement is moderate for 9 percent of the treatment areas in the action alternative, indicating some erosion is likely if mineral soil remains exposed to rainfall. Skid trails down short steep slopes, when unavoidable, need to be stabilized with simple erosion control measures such as covering with logging slash or constructing water bars to protect exposed mineral soil until the site is re-vegetated. Slopes may range up to 35 percent, but commonly have 15 to 25 percent gradients. Operation of equipment on slopes approaching 30 percent should be avoided where possible through treatment area layout, or trees should be cut by hand and cabled from above or below. Harvesting machines may also reach trees from above and below on short steep areas. Keeping equipment off of steep areas and cabling trees will avoid exposing excessive mineral soil. Appendix A of this report lists site-specific stands where steep slopes are a limiting factor. Implementing appropriate erosion control measures for exposed mineral soil on steep slope areas will reduce the potential risk for erosion from moderate to slight.

The potential for erosion and displacement is severe for 3 percent of the proposed treatment areas, indicating erosion is likely if mineral soil remains exposed to rainfall. Slopes range from 20-45%. Operation of equipment on slopes exceeding 30% should be avoided through treatment area layout, or trees should be cut by hand and cabled from above or below. Harvesting machines may also reach trees from above and below on short steep areas. Keeping equipment off of steep areas and cabling trees will not expose excessive mineral soil and risk of erosion would then be slight. Appendix A of this report displays where steep slopes are a limiting factor.

The forest floor cover such as litter, slash and surface rock protects the soil from erosive forces of raindrop impact and runoff. An undisturbed and totally covered forest soil usually yields no surface runoff, thus, it has no sheet and rill erosion (Dissmeyer and Foster, 1980, p7). Tracked or rubber tired harvesting machines (fell, limb and cut to length) and rubber-tired forwarders (haul) are used in 90 percent of the tree harvest operations in the project area and the average ground traveled is 11 percent or less of a sale unit for all harvest types (Schumacher, 2002). The two machines typically operate on the same trails and run on top of slash generated from the harvested trees surface rock and forest floor litter. Potential to expose mineral soil is minimal. Verry (1972, p283) found no evidence of accelerated erosion after clear-cutting an aspen stand in Minnesota. A few scattered areas (25-50sq ft each) of exposed soil may occur within harvest areas due to maneuvering tracked machines over uneven ground. These isolated areas will re-vegetate naturally within one or two growing seasons and are not an erosion concern. Operation of this type of harvesting equipment does not remove the surface organic or mineral soil layers, thus, soil displacement rarely occurs. In some harvest operations, full-length trees are pulled to a landing with a grapple skidder, allowing the limbed tree-tops to drag on the ground. This will cause some mixing of the organic and mineral soil materials but is not considered detrimental displacement (USDA Forest Service, 2012a).

Log landing (described in the previous section) are often located on open areas adjacent to woods roads and the wood is placed directly on the undisturbed ground surface. A landing “spur” within or adjacent to a harvest unit, may be approved by the Sale Administrator, when decking wood along the haul road is not permitted. A spur typically is an area about 40 feet by 100 feet and wood is placed on undisturbed ground, if possible. Some spurs may require clearing of trees, stumps, rocks or other debris. Some soil may be displaced in this process. Potential for soil erosion of either type of log landing is very low because level, well drained upland areas are generally designated and natural ground cover is kept in place, or if removed, would be re-established by natural or artificial seeding within one or two growing season. Main forwarder/skid trails near landing areas would have more exposed mineral soil due to repeated use. These areas would also re-

vegetate naturally within two growing seasons, or be stabilized with a slash cover or other erosion control measures through the timber sale contract, as needed.

Potential for soil erosion and displacement exists when mineral soil is exposed during the road construction process. All road construction projects follow CNNF LRMP 2004 guidelines on page 2-38 that require utilizing Wisconsin Forestry Best Management practices (WDNR, 2010) Forest Plan standards and guidelines for Soil, Water Resources and Transportation Systems would be followed. No detrimental soil erosion would be expected. Detrimental soil displacement would occur on portions of the new temporary roads (0.2 miles proposed) where the organic surface and more than one inch of mineral soil may be bladed off when removing stumps and debris to prepare the roadbed. These temporary roads would be decommissioned upon completion of vegetation management activities and proven soil stabilization practices such as water bars, seeding, and mulching would be applied where appropriate following Wisconsin Forestry BMPs (WDNR, 2010 No long-term detrimental displacement effects to the project area are expected from temporary road construction and use. New permanent forest roads (1.2 miles proposed) and existing re-constructed roads (46.5 miles proposed) would be maintained as part of the transportation system necessary to manage the forest and provide public access for recreation. The lands committed for use as “system” roads, and trails, and other administrative facilities are not considered detrimentally disturbed conditions.

The newly decommissioned roads (147.2 miles) for this project may be disked to loosen compaction, which would expose and displace some mineral soil in the process. New temporary roads constructed for this project may be disked to loosen compaction, which would expose and displace some mineral soil in the process. However, these roads would most likely be allowed to re-vegetate and rely on natural processes to eliminate compaction, returning this land to productive forest over time. In either case, the goal is to stabilize these sites and eliminate erosion potential. Mitigation measures would be identified, as needed, to further minimize potential for erosion while these sites are stabilized.

Mechanical site preparation to prepare the ground surface for planting or natural regeneration of targeted tree species is proposed for a maximum of 354 acres of the harvested areas in the action alternative. Erosion and displacement risk is slight for 53 percent, moderate for 40 percent, and severe for 7 percent of the site prep areas in in the proposed action alternative. The moderate rating is due to slopes ranging from 15 to 35 percent and the severe rating is for areas with slopes ranging above 35 percent. The remaining 53 percent proposed for mechanical site preparation treatment in the action alternative is rated slight for erosion and equipment operation due to slopes ranging from 0 to 15 percent. The tractor or skidder attached equipment that would be used (roller chop, disc trench, or salmon blade) to prepare 50 to 75 percent of the sites for planting or natural regeneration would not expose enough continuous mineral soil for there to be an erosion concern, even on the steeper slope areas. Soil on the steeper sites is primarily well drained with sandy loam surface textures beneath the forest floor organic materials. Infiltration and permeability rates are moderately rapid in the surface and rapid to very rapid in the subsurface layers, indicating water readily enters and moves through the soil, with low run off potential. Equipment used to scarify the surface will cause some mixing of the organic and mineral soil materials, but this is not considered detrimental displacement (USDA Forest Service, 2012a). Areas where forest floor materials are scraped away exposing areas of mineral soil would be scattered and discontinuous with good infiltration so surface erosion would not be expected, even on the areas with steeper slopes. The exposed mineral soil areas will re-vegetate naturally within one or two growing seasons and no surface erosion is likely. See Appendix A of this report for sites where steep slopes may be a limiting factor.

The proposed action alternative proposes prescribed burning of 334 acres to prepare oak, jack pine and/or paper birch stand sites for natural regeneration. Low to moderate intensity broadcast burning would not totally consume the organic layer, or create water repellent conditions, or expose enough mineral soil to allow surface erosion. A line of bare mineral soil will be constructed around the perimeter of most burn areas as a firebreak and will total about 5.3 miles for proposed prescribed burns in the action alternative. The organic layer and upper 2 inches of mineral soil would be displaced to the side of the fire break by a tractor and fire plow (about 8 feet wide), or dozer blade (up to 15 feet wide). The exposed soil for control lines would seed in naturally or would be artificially seeded to establish ground cover within 2 growing seasons. Water bars would be constructed, if needed, on short steep slope areas. There would be short term detrimental displacement of soil along the entire length and width of these constructed firebreaks, with no detrimental surface erosion expected.

About 229 acres of Wildland Urban Interface (WUI) hazardous ladder fuel reduction and slash disposal in the action alternative will be accomplished through the timber sale activities described, through balsam bough cutting permits, or by hand removal. There is no additional risk of soil erosion or displacement from this activity.

Geologic erosion would continue at a minimal rate of less than 0.18 tons/acre/year (Patric, 1976, p572). Patric (1976, p576) also notes the overwhelming weight of evidence supporting the view that soil losses from responsibly managed forest land are slight compared to those that accompany most other land uses.

In summary, all proposed ground disturbing activities would be designed to eliminate or minimize potential for soil erosion and displacement. Where possible, avoid operation of heavy equipment up and down steep slope areas approaching 30 percent gradients where exposed soil will readily erode. Locate roads and landings on level ground and stabilize exposed soil on steep slopes during and after use to control erosion. The following Forest Plan guidelines would apply to all treatment areas (see Appendix A).

- Designate the location of roads, trails, landings, main skid trails, and similar soil disturbing activities. Stabilize disturbed sites during use and re-vegetate after use to control erosion (USDA Forest Service, 2004d, p. 2-3).
- Minimize road impacts by utilizing soil protection measures described in WDNR Forestry Best Management Practices, 2010

There would be no short or long-term detrimental soil disturbance effects from soil erosion on project sites or adjacent areas, when Forest Plan Soils and Transportation System guidelines are followed. There would be short-term detrimental disturbance effects from soil displacement on the project sites where landing areas, back in spurs, or temporary roads require clearing of stumps, rocks and other debris. No treatment areas or adjacent areas in the Fourmile Project would suffer long-term impairment of the soil resource from erosion or displacement, should the action alternative be implemented.

Effects to Soil from Prescribed Fire

There is potential for soil impacts to 334 acres proposed for prescribed fire in the action alternative. Also see the prescribe burn and fire control line discussions specific to soil compaction, rutting, erosion and displacement in the two previous sections.

A moderate to high intensity prescribed burning would be desired to reduce competing vegetation, open serotinous cones (jack pine) and provide a favorable mineral soil seedbed for natural regeneration of oak, jack pine, or paper birch. Fire is the natural disturbance regime of the dryer portions of the outwash plains landform, with sandy soils and associated/adapted vegetation. The treatment areas proposed for prescribed fire have a history of natural, large and small, low to high intensity fires. Up to 100 percent of the ground in a burn unit may be affected by the fire, or less depending on fuels and conditions. Fuels would consist of scattered slash from shelterwood (oak and paper birch), or clearcut (jack pine) harvest operations. Burning would be done in the spring or fall when the litter layer is moist. The severity and duration of a prescribed fire determines the effects on the physical, chemical and biological properties of the soil. While a “hot burn” is desired to accomplish the natural regeneration objectives, a low to moderate intensity broadcast burn is most likely, given the fuel types/loading and prescribed burn plan required conditions for burning. Thus, a mechanical treatment fall back option is also planned for all proposed prescribed fire areas. Low ground surface temperature prescribed fires combust only surface fuels and transfer little heat downward. The proposed controlled fires would not be severe with no areas of heavy fuel buildup like slash piles or windrows of debris. A portion of the under story vegetation and forest floor debris would be burned. Prescribed fires seldom remove more than 50 percent of the surface organic layers and the soil organic fraction of the A horizon is not generally affected by light burns (Pritchett and Fisher, 1987, p403). Effects to the soil resource from the prescribed burning proposed in the action alternative of the Fourmile project may include (after Pritchett and Fisher, 1987, pp403-416): an increase in available phosphorous, potassium, calcium, and magnesium for 1-5 years; increased surface and mineral soil carbon, increase in pH; some nitrogen loss through volatilization and leaching, with temporary increased availability to re-sprouting vegetation; minimal increase in mineral soil temperature during the burn due to moist, insulating humus layer; minimal increase in soil surface temperature until vegetation covers the blackened surface; initial decrease in soil microbes and

bacteria followed by sharp increases as rainfall leaches nutrients into the soil; a decrease in earthworm populations; and an increase in soil animals such as arthropods e.g. beetles, ants, centipedes, millipedes, springtails, spiders, ticks, mites.

Grossman and Mladenoff (2008, p831) studied long-term effects of disturbance on soil organic matter, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and pH on the dryer sand plain/barrens and noted that quick recovery of the fire adapted vegetation helps to limit leaching losses and aids in organic matter and nutrient recovery. Lynham et al. (1998, p93) found soil chemical changes were small or they rebounded to pre-burn levels within 10 years after burning. Lynham et al. (1998, p102) also found total nitrogen gradually increasing in the mineral soil layers for up to 10 years after burning, which more than compensated for the initial loss of nitrogen in the fire. In boreal jack pine forests, soil nitrogen gradually rebuilds from N-fixation associated with sweetfern (Comptonia peregrina) (Grossman and Mladenoff 2008, p828; Lynham et al., 1998, p 97), a common shrub in the project area jack pine stands on sand soils. Johnson (1992, p96) found prescribed fire usually caused a reduction in forest floor weight, but either no change or an increase in mineral soil carbon. An increase in surface soil carbon after prescribed burning would likely be caused by incorporation of charcoal and partially burned organic matter into the mineral soil. In a meta-analysis of fire effects on soil carbon (C) and nitrogen (N) Johnson and Curtis (2001, p232-233) found no significant effect on total C or N in the A horizon or the whole mineral soil from either prescribed or wildfire.

There would be no short or long-term detrimental soil disturbance effects from the prescribed burning proposed in the action alternative. The intensity and duration of the burns would not be severe (as defined on page 4) and would not impair soil physical, chemical or biological properties.

Soil Productivity

The potential for activities in the action alternative to impact inherent soil productivity of the proposed treatment area is low. Soil productivity could be reduced from the proposed activities if excessive organic matter and nutrients were removed through harvesting, prescribed fire, soil erosion, or soil displacement. Productivity could also be reduced if soil physical properties such as structure or porosity, were impaired by compacting or rutting soil beyond acceptable limits for a treatment area. Potential for detrimental long-term soil impacts from compaction, rutting, erosion, and displacement are determined to be low, as described in the two previous sections, indicating the proposed actions will not adversely affect the inherent productivity of the soil resource in the treatment areas.

The proposed action alternative includes about 1.2 miles of new road construction (20’ maximum clearing width assumed), which would compact new soil areas and change the land use for about 2.9 acres of land from productive forest to part of the permanent transportation system used to manage the CNNF. About 46.5 miles of existing road reconstruction involves land already removed from the productive land base for transportation and does not constitute a change to soil productivity. Decommissioning 147.2 miles of existing roads in in the action alternative would return about 214 acres (assuming a 12’ road bed) to productive land over time.

New temporary road construction of about 0.2 miles proposed in the action alternative would remove about 0.7 acres (assuming a 28’ maximum clearing width) of productive soil resource for the short term. These temporary roads would be decommissioned and restored to productive land over time, when project activities are completed.

Mechanical site-preparation to mix the forest floor organic material with the underlying mineral soil surface horizon, as described in the previous sections, is expected to increase long-term site productivity of the forest community through successful establishment, survival and growth of the desired pine, spruce or paper birch tree species on up to 354 acres. Perala and Alm (1989, p152) found mineral soil seed beds were absolutely necessary for paper birch seed germination in the Lake States and seedlings grew best if greater than 1 inch woody debris material was incorporated into the seedbed for increased water storage, phosphorus, nitrogen and mycorrhizal inoculum availability. Mallik and Hu (1997, p274) studied the effects of site preparation treatments in a boreal mixed-wood forest and found that site preparation equipment with soil surface mixing capability, such as the salmon blade equipment proposed for this project, improves soil nutrient status by increased organic matter decomposition and creates better site conditions for enhancing the growth of planted conifers. Treatments like harvesting that disturb the forest floor or mechanical site preparation that

mix organic layers into mineral soils can lead to a more diverse microbial population for the short term due to better soil aeration and improvement in substrate quality (Mallik and Hu 1997, p272). There are no short or long-term detrimental effects to soil productivity expected from the mechanical site preparation treatments proposed in the action alternative.

The action alternative proposes to treat a total of 11,803 acres, to increase stand health and vigor, and address other Fourmile project area needs as described by the purpose and need and proposed action documentation. Harvest types proposed in overall include: clearcut with reserve trees 1,191 acres, and; partial cut by thin, selection, improvement, overstory removal, salvage, sanitation, or shelterwood 10,612 acres.

Cutting trees and removing the merchantable bole or whole-tree (bole plus crown) would remove a portion of the treatment area organic matter and nutrients (N, P, K, Ca, and Mg). The ratio and amount of nutrients in tree components (e.g. foliage, branches, bole, bole bark, stump and roots) and thus, the amount removed, varies by species, age, stocking and site quality. Alban et al. (1978) determined the organic matter and nutrient distribution in vegetation and soil for aspen, white spruce, red pine and jack pine on the similar soil types in northern Minnesota. They found most nutrients are concentrated in the soil, with only 6 to 23 percent of the N, Ca, and Mg, and only 21 to 50 percent of the P and K found in the vegetation (includes a small percentage of each nutrient in the understory vegetation). Perala and Alban (1982, p184) found the species order of nutrients in trees on both a loam and sand soil to be aspen>spruce>red pine>jack pine for all nutrients, except red pine>spruce for Mg. Oaks are similar to aspen in accumulating relatively large amounts of nutrients, especially calcium (Johnson and Todd 1987, p 101). Pastor and Bockheim (1994. p 348) found nutrient concentrations in aspen to be higher than mixed hardwoods (sugar maple) on the same soil in Vilas County, Wisconsin. About 50 to 60 percent of the above ground tree nutrients for both hardwoods and conifers are in the bole, of which half is in the bole wood and half in the bole bark (Alban et al. 1978, p294, Mann 1988, p415). Nutrient removal from merchantable bole and bark harvest is not considered excessive, as these nutrients can generally be replaced by mineral weathering and atmospheric deposition (Silkworth and Grigal 1982, p626). Also, bole-only harvest areas retain nutrients in: forest floor organic materials (humus layers), mineral soil nutrient capital, tree stumps, decaying root systems, existing fine and coarse woody debris, top wood stem, foliage and branches (slash), remaining trees (if thinning), shrub and herb layer, and in the 10 to 15 percent or more of tree biomass that is not removed due to breakage during harvest (Alban and Perala 1990, p386; Grigal 2004, p14-22). Leaching of nutrients below the rooting zone occurs naturally and would be increased for a short time (following the disturbance of bole only harvesting. Silkworth and Grigal (1982, p630) found leaching losses of N, P, K, and Mg to be less than inputs by precipitation and weathering.

Long term studies specific to harvesting aspen and the effects on soil carbon and nutrient pools have been researched heavily through the Lake-States Long Term Soil Productivity Study. Slesak et al. (2017 p70 and 73) found that 20-year response to changes in soil physical and chemical properties following soil organic matter removal and compaction show that, regardless of treatment, and in most cases, soil carbon and nutrient pools tend to increase in the first decade, followed by decreased or stable pools in the second decade. Additionally, their general conclusion is that there is little evidence for degradation of soil carbon and nutrient pools with commonly used harvesting techniques in aspen ecosystems.

Soil respiration (SR), also referred to as soil-CO2 evolution or soil-CO2 efflux, is the total CO2 production/release in intact soils resulting from the respiration of soil organisms, roots, and mycorrhhizae, and is a major flux in the global carbon cycle (Raich and Schlesinger, 1992, p81-82). This activity is sustained by organic matter inputs to soil from above (surface litter) and below ground (root detritus), with annual soil respiration rates primarily controlled by seasonal soil temperature and soil moisture, among vegetation types at the landscape scale (Zheng et al., 2005, p170). Laporte et al. (2003, p566) noted contradictory results from multiple studies monitoring soil surface CO2 efflux after forest harvesting, with increases, decreases, and no effect to soil respiration documented after logging disturbance. Comparing northern hardwoods single tree selection, shelterwood, and clear felling with an uncut control, Laporte (2003, p572) found logging had limited impact on overall SR, but emphasized microsite differences, noting lower soil respiration on the drier and warmer mechanically disturbed or scarified microsites during the growing season following harvest. Mallik and Hu (1997, p272) found increased soil respiration following site preparation in the mixed wood aspen-balsam fir-white spruce-black spruce-paper birch type due to soil mixing that accelerated microbial activity and increased organic matter decomposition, however, soil temperature was not increased enough to make a significant difference in SR. Weber (1990, p11) found soil respiration rates returned to pre-treatment levels

after three growing seasons following aspen clear-cuts, and clear-cut and burned treatments. Striegl and Wickland (1998, p538) found clearcutting mature jack pine reduced CO2 emission by 60 percent in the first growing season, but expected soil respiration and photosynthetic uptake should increase substantially in the years following a clearcut, as surface-soil microbial communities re-establish, tree roots decompose, and rooted ground cover plants and trees are re-established. A recent study (Tang et al., 2008) used a chronosequence approach to study age succession of soil carbon fluxes and stocks on the Chequamegon-Nicolet and Ottawa National Forests. Soil respiration and carbon stocks were measured on a recent clearcut and burned stand, a blowdown and partial salvage stand, a clearcut with residual overstory, a complete clearcut, young and intermediate aged aspen stands, mature northern hardwoods, and old growth stands. Soil respiration increased during stand establishment, peaked at intermediate age, and then decreased with age. Total soil carbon at 0-60 cm initially decreased after harvest, and then increased after stands established, compensating the loss of carbon during harvest (Tang et al., 2008, pp145 and 153). Removal of merchantable tree boles or whole trees (bole plus crown), prescribed fire, and mechanical site preparation will affect soil respiration rates and carbon uptake following treatments proposed in the action alternative, but will be expected to return to pre-treatment levels as studies suggest, without detrimental effects to the long-term productivity of the land or to the carbon balance of ecosystems from a local to global scale.

Soil organic carbon was assessed in the 2004 CNNF FEIS (USDA Forest Service. 2004c, p3-39, 3-84, p3-93), which indicates through the literature cited that the CNNF would continue to be a carbon sink, little to no change in soil carbon could be expected after all types of forest harvesting proposed, and projects an increase in soil carbon storage through implementation of the CNNF Forest Plan. More recent studies specific to Wisconsin forests indicate the CNNF to be a net sink of carbon, even after accounting for all associated emissions (Gower and Ahl. 2006, p50). Ten year results from a North American long-term soil productivity experiment, with harvest plots in Minnesota and Michigan, indicate when forest floors are retained there is no general decline in soil carbon with time, slash removal does not reduce soil carbon storage to 30 cm through 10 years, and the primary inputs to soil carbon come from the decay of fine roots that remain from the harvested stand, not the logging slash (Powers et al., 2005, p44-45). Soil organic carbon would be increased initially on all harvest treatment areas for all alternatives, due to the decaying roots systems of the harvested trees.

Natural soil formation processes would continue, biomass and organic matter would accumulate from the open lands and managed forest vegetation and be incorporated into the soil surface, and the biological and geo-chemical nutrient cycles would continue. Inputs to the system include atmospheric deposition and weathering of mineral soil parent materials. Annual nutrient balances based on estimated inputs and outputs would tend to increase as succession progresses (Pritchett and Fisher, 1987, p190).

Considering all potential effects to the soil resource discussed above, I estimate that treatments proposed in the action alternative would have no long-term direct or indirect detrimental effects to soil productivity of project sites. Long-term productivity of the land would be maintained on more than 97 percent of all treatment areas.

Cumulative effects:

The analysis boundary for soils cumulative effects was determined to be the Land Type Phases (LTP) within treatment areas for the Fourmile Project. Landtype phases are mapped ecological units whose natural boundaries best define site-specific soil resource information on the CNNF. Expanding the cumulative effects analysis area would only serve to dilute the effects to soils from all proposed project activities by including lands with no existing detrimental soil conditions and no present or future plans for treatment. Since analysis has indicated negligible off-site erosion potential, cumulative impacts to the soil resource in the project area would not affect surrounding LTPs on federal land or land in other ownerships. Potential effects to the soil resource are reasonably confined to the soil directly beneath where the activity would take place, such as the operation of machinery to cut and remove trees. For example, heavy equipment causing soil compaction that reduces pore space for air, roots and water within a portion of one treatment area does not affect pore space on adjacent areas. System roads, trails, and other administrative facilities are dedicated land uses necessary to access and manage the CNNF and are not considered detrimental soil conditions when assessing cumulative affects to soil quality within or adjacent to the project area. The permanent transportation system on the CNNF continues to be reduced over time. The 2011 Travel Management Project and motor vehicle use map (MVUM) commits a relatively small amount (0.21 %) of the CNNF land base to motor vehicle use,

compared to the 4,656 miles (8,102 acres or .54% of the CNNF) that were open to motor vehicles in 2008 (USDA Forest Service, 2011b, p2). The time span for cumulative effects analysis for the soil resource is the past 30 years. This time period is chosen because the CNNF has data records of harvest activities for this time period that allows consideration of multiple harvest impacts per treatment area. Also, soil impacts, particularly detrimental soil compaction, may take several decades for natural recovery. The period of time for natural recovery varies by soil characteristics and severity of compaction and while freeze-thaw cycles may hasten recovery, the effects may be assumed to persist for several decades (NCASI, 2004 p62).

In 2017, the CNNF conducted a soil monitoring study that was designed to quantify natural soil recovery (amelioration) at 10, 20, and 30 years post-harvest. (USDA Forest Service, 2017b) The “indicator” soil type chosen for this study had a silt loam surface texture, and a seasonally high water table (moderately well drained). This soil type (Alfic Oxyaquic Fragiorthods) was also chosen because of its’ rich mesic habitat type (AOCa), forest products economic value (Hardwood), its’ comparatively high susceptibility to rutting and compaction (soil strength), and presence of a fragipan which contributes to periodic episaturation conditions. Of the 546 random sample locations in the study, which spanned a time-frame of 10 to 30 years post-harvest, approximately 0.2 percent of the total area remained in detrimental disturbed conditions as defined in the Measures, Indicators, and Thresholds section above. Furthermore, at the 10 to 20 year post-harvest recovery interval, no detrimental soil disturbance was detected which supports the effectiveness of current soil protection measures. As a conservative estimate however, 0.5 percent is being used to quantify past disturbance carried-forward for the cumulative effects analysis.

Past Actions

Numerous historic, natural and human caused ground disturbing events, such as, windstorms, turn of the century (late 1800’s to early 1900’s) logging and associated fires, road and railroad building, have taken place in and around the area of cumulative effects analysis. While these events have influenced the existing condition of the soil resource, there are no known adverse residual impacts.

Activities, such as, timber harvesting and road building, have occurred over the past 30 years and were implemented following contract operating restrictions, Land and Resource Management Plan standards and guidelines (1986 to present), and site specific design measures to mitigate soil resource impacts on Forest Service lands. The CNNF End of Decade Monitoring Report (USDA Forest Service, 1998a, p65) covering management activities implemented between1986-1996 indicated no appreciable effects to the long term productivity of the land. About 6,439 acres (54%) of the stands proposed for treatment have had no previous harvest, and about 5,521 acres (46%) have had one or more previous harvests in the past 30 years; as documented in the CNNF timber stand history files. These activities have left less than 1 percent of those areas in a detrimentally disturbed condition from compacted skid trails, landings, or temporary roads. On-site monitoring of soil resource impacts across the Eagle River-Florence District has shown no long-term impairment of the land from similar project activities on the same soil types as listed in Table 1. (USDA Forest Service, 2000a, 2002a, 2004b, 2006c, 2007c, 2015b) Site-specific field monitoring by myself and other resource specialists within the Fourmile Project has verified that there are no proposed treatment areas with long-term impairment (detrimental disturbance is within threshold values listed on p4 above) to the soil resource from past activities. As a conservative estimate, about 0.5 percent (60 acres) of the proposed treatment areas (11,803 acres) will be considered disturbed from any and all past activities. More than 99 percent of the managed soil resource in the proposed treatment areas is maintained in a non-detrimentally disturbed condition. The Forest has also implemented Wisconsin Forestry Best Management Practices for Water Quality since 1995 and recent field monitoring indicates that 99 percent of the time there will be no adverse impacts to water quality from soil erosion/sedimentation when BMPs are applied correctly (Cooper et al, 1998, p62; Holland, 2003, p16-18, Shy and Wagner, 2007, p33). Current conditions indicate key soil properties affecting ecosystem health and sustainability such as porosity, organic matter content and nutrient availability are representative of the natural range of soil conditions inherent to the landscape of the Chequamegon-Nicolet NF (USDA Forest Service, 1998b, p6). Healthy populations of soil microorganisms such as bacteria and fungi exist in the favorable environment of the forest floor litter layer and soil surface organic matter (Pritchett and Fisher, 1987, p77), which will remain in place.

No appreciable long-term effects to the soil resource or long-term productivity of the land from past activities have been identified in the proposed treatment areas for the Fourmile Project.

Present and Reasonably Foreseeable Actions

The Fourmile Project proposes actions that would include ground-disturbing activities. Assessment of potential direct and indirect impacts from activities in the action alternative indicates that at most another 2 percent of the treatment areas may be detrimentally compacted by heavy equipment. However, based on Region 9 soil threshold values discussed on page four of this report, no appreciable short or long-term detrimental soil disturbance would be expected. Monitoring indicates adherence to CNNF Land and Resource Management Plan standards and guidelines, site-specific design measures, and contract provisions would eliminate or minimize potential adverse impacts from compaction, rutting, erosion, displacement, burning, or nutrient removal. About 97 percent of the managed soil resource on federal land within the proposed treatment areas would be maintained in a non-detrimentally disturbed condition.

There are no other projects decisions with ground disturbing activities planned that remain to be implemented that would have any direct, indirect, or cumulative effects to the soil resources within the Fourmile Project treatment areas.

The 2004 Land and Resource Management Plan FEIS soils effects analysis on page 3-82 stated that of the 1,494,000 acres of CNNF land, 1.3 to 1.5 percent is projected to have potential ground disturbing activities proposed annually through the first decade for all alternatives, leaving more than 98.5 percent with no disturbance, and 85 percent undisturbed over the decade. The actual average annual harvested area from 2004-2010 was 8,990 acres, or 0.60 percent per year. This was less than ½ the predicted amount, leaving 99.4 percent undisturbed annually and 95 percent undisturbed over the first decade. Annual harvest area from 2006 to 2015 (10 years) averaged slightly less at 8,803 acres, or 0.59 percent per year.

No appreciable long-term effects to the soil resource or long-term productivity of the land from present and reasonably foreseeable activities have been identified in the project area.

Future Actions

At this time there are no other specific actions known to be planned within the Fourmile Project area of cumulative effects analysis for the soil resource.

CONCLUSIONS

The effects of implementing one of the proposed alternatives when added to the effects of past, present, and reasonably foreseeable actions would not be expected to result in appreciable adverse cumulative effects to the quality of the soil resource in the project area.

Table 5. Summary of Direct/Indirect and Cumulative Soil Detrimental Disturbance

Soil Resource Impacts	No-action Alternative Acres (%)	Action Alternative Acres (%)
Total treatment Area	0	11,803
Direct and indirect long-term detrimental disturbance (predicted)	0	236 (2)
Past detrimental disturbance	60 (0.5)	60 (0.5)
Cumulative detrimental disturbance	60 (0.5)	296 (2.5)
Long-term productive soil resource	11,900 (>99)	11,507 (>97)

More than 99 percent of the proposed treatment areas are currently in good condition and soil properties are well within their natural range of variability. Soils on project sites pose a low risk potential for detrimental disturbance from the conventional ground-based logging, mechanical treatments, prescribed fire, and transportation system activities proposed. The project would adhere to identified Forest Plan standards and guidelines and resource protection measures for specific soil types, eliminating or minimizing potential adverse soil resource impacts. At most, an additional 2 percent of the soil resource in the treatment areas would sustain long-term detrimental impacts from the above proposed activities. More than 97 percent of the treatment areas in the action alternative would remain in a non-detrimentally disturbed condition, which meets National and Regional soil quality standards discussed on pages 3 and 4 above. Based on minimal direct and indirect effects on soil compaction, rutting, erosion, displacement, or productivity, the action alternative would not impair the long-term productivity of the areas proposed for treatment or adjacent areas. This determination is based on the best available science including; literature reviews, peer reviews, and ground-based observations.

Irreversible and Irretrievable Commitments of Resources

No irreversible or irretrievable commitments of the soil resource will occur by implementing the action alternative.

Consistency with the Forest Plan

All alternatives comply with the Forest Plan direction pertaining to the soil resource.

Monitoring Plan

During project implementation proposed treatment areas (harvest, site preparation, and road construction) would be monitored by Forest Service personnel to ensure contract specifications and design measures are followed. Randomly selected treatment areas would be monitored post harvest by the forest soil scientist as part of a forest-wide soil monitoring program, to evaluate whether ground conditions meet acceptable limits of change for measurable and observable soil properties. Annual timber sale implementation and effectiveness reviews, including effects to soils, are conducted across the Forest by interdisciplinary teams on randomly selected completed harvest units. Future reviews on the Eagle River-Florence unit would most likely include treatment areas from the Fourmile Project area.

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Appendices

A – Soils Specialist Report Fourmile Appendix A - Project Action Alternative site specific soil resource information for treatment areas

B - Soils Specialist Report Fourmile Appendix B - Project Action Alternative site specific soil resource information for road treatments

Signature:

Mark Farina

Forest Soil Scientist

Chequamegon-Nicolet NF

Qualifications: Bachelor of Science- University of Wisconsin- Stevens Point, December 1998

Major: Soil Science

Professional Experience as a Soil Scientist, 18 years:

Natural Resources Conservations Service, Michigan, 1998-2015

Terrestrial Ecological Land Classification Contractor, 2006-2015

National Park Service Soil Inventory Contractor, 2006-2015

Forest Soil Scientist-Chequamegon-Nicolet NF, 2015-present